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(54) Image-forming apparatus.

(57) An image-forming apparatus comprises a back plate carrying thereon a plurality of electron-emitting devices, a face plate arranged vis-a-vis the back plate and carrying thereon a fluorescent member and an anti-atmospheric-pressure spacer. The longitudinal axis of the anti-atmospheric-pressure spacer is arranged substantially in parallel with the direction of deflection of electron beams emitted from said electron-emitting devices.

EP 0 631 295 A2

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to an image-forming apparatus such as a display apparatus and, more particularly, it relates to an image-forming apparatus comprising a spacer arranged inside the apparatus.

Related Background Art

There have been known two types of electron-emitting device: the thermoelectron type and the cold cathode type.

Of these, the cold cathode type includes the field emission type (hereinafter referred to as the FE-type), the metal insulation layer metal type (hereinafter referred to as the MIM-type) and the surface conduction type.

Examples of the FE electron-emitting device are described in W. P. Dyke & W. W. Dolan, "Field emission", Advance in Electron Physics, 8, 89 (1956) and C. A. Spindt, "PHYSICAL Properties of thin-film field emission cathodes with Molybdenum cones", J. Appl. Phys., 47, 5284 (1976). MIM devices are disclosed in papers including C. A. Mead "The tunnel-emission amplifier", J. Appl. Phys., 32, 646 (1961). Surface conduction electron-emitting devices are proposed in papers including M. I Elinson, Radio Eng. Electron Phys., 10 (1965).

A surface conduction electron-emitting device is realized by utilizing the phenomenon that electrons are emitted out of a small thin film formed on a substrate when an electric current is forced to flow in parallel with the film surface. While Elinson proposes the use of SnO_2 thin film for a device of this type, the use of Au thin film is proposed in G. Dittmer: "Thin Solid Films", 9, 317 (1972), whereas the use of In_2O_3 SnO_2 thin film and the use of carbon thin film are discussed respectively in M. Hartwell and C. G. Fonstad: "IEEE Trans. ED Conf.", 519 (1975) and H. Araki et al.: "Vacuum", Vol. 26, No. 1, p. 22 (1983).

Fig. 22 of the accompanying drawings schematically illustrates a typical surface conduction electron-emitting device proposed by M. Hartwell. In Fig. 22, reference numerals 1011 and 1013 respectively denote a substrate and an electrically conductive film, which is normally prepared by producing an H-shaped thin metal oxide film according to a given pattern by means of sputtering, part of which eventually makes an electron-emitting region 1012 when it is subjected to an electrically energizing process referred to as "electric forming". In Fig. 22, the thin horizontal area of the metal oxide film separating a pair of device electrodes has a length L of 0.5 to 1mm and a width W' of 0.1mm. Note that the electron-emitting region 1012 is only very schematically shown because there is no way to accurately know its contour and location.

As described above, the conductive film 1013 of such a surface conduction electron-emitting device is normally subjected to an electrically energizing preliminary process, which is referred to as "electric forming", to produce an electron-emitting region 1012. In the electric forming process, a DC voltage or a slowly rising voltage that rises typically at a rate of 1V/min. is applied to given opposite ends of the conductive film 1013 to partly destroy, deform or transform the thin film and produce an electron-emitting region 1012 which is electrically highly resistive. Thus, the electron-emitting region 1012 is a part of the conductive film 1013 that typically has fissures therein so that electrons may be emitted those fissures.

Note that, once subjected to an electric forming process, a surface conduction electron-emitting device comes to emit electrons from its electron-emitting region 1012 whenever an appropriate voltage is applied to the conductive film 1013 to make an electric current run through the device.

Since a surface conduction electron-emitting device as described above is structurally simple and can be manufactured in a simple manner, a large number of such devices can advantageously be arranged on a large area without difficulty. As a matter of fact, a number of studies have been made to fully exploit this advantage of surface conduction electron-emitting devices. Applications of devices of the type under consideration include charged electron beam sources and electronic displays.

In typical examples of application involving a large number of surface conduction electron-emitting devices, the devices are arranged in parallel rows to show a ladder-like shape and each of the devices are respectively connected at given opposite ends with wires (common wires) that are arranged in columns to form an electron source (as disclosed in Japanese Patent Application Laid-open Nos. 64-31332, 1-283749 and 1-257552). As for display apparatuses and other image-forming apparatuses comprising surface conduction electron-emitting devices such as electronic displays, although flat-panel type displays comprising a liquid crystal panel in place of a CRT have gained popularity in recent years, such displays are not without problems. One of the problems is that a light source needs to be additionally incorporated into the display in order to illuminate the liquid crystal panel because the display is not of the so-called emission type and, therefore, the development of emission type display apparatuses has been eagerly expected in the industry. An emission type

characterized in that the longitudinal axis of the anti-atmospheric-pressure spacer is arranged substantially in parallel with the direction of deflection of electron beams emitted from said electron-emitting devices.

According to the invention, there is also provided an image-forming apparatus comprising a back plate carrying thereon a plurality of electron-emitting devices, a face plate arranged vis-a-vis the back plate and carrying thereon a fluorescent member and an anti-atmospheric-pressure spacer, characterized in that a device-side rib is arranged on the back plate, projecting from the back plate higher than any of the electrodes of the electron-emitting devices, and a fluorescent-layer-side rib is arranged on the face plate, projecting from the face plate higher than the fluorescent layer, said anti-atmospheric-pressure spacer being held in contact with the back plate and the face plate respectively by way of the device-side rib and the fluorescent-layer-side rib.

According to the invention, there is also provided an image-forming apparatus comprising a back plate carrying thereon a plurality of electron-emitting devices, a face plate arranged vis-a-vis the back plate and carrying thereon a fluorescent member and an anti-atmospheric-pressure spacer characterized in that the longitudinal axis of the anti-atmospheric-pressure spacer is arranged substantially in parallel with the direction of deflection of electron beams emitted from said electron-emitting devices and that a device-side rib is arranged on the back plate, projecting from the back plate higher than any of the electrodes of the electron-emitting devices, and a fluorescent-layer-side rib is arranged on the face plate, projecting from the face plate higher than the fluorescent layer, said anti-atmospheric-pressure spacer being held in contact with the back plate and the face plate respectively by way of the device-side rib and the fluorescent-layer-side rib.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a schematic overall perspective view of a first embodiment of image-forming apparatus according to the invention.

Fig. 1B is a partially cutaway schematic perspective view of the embodiment of Fig. 1A, which is aslo common to second through tenth embodiments of the invention.

Fig. 1C is a schematic overall perspective view of a fourth embodiment of image-forming apparatus according to the invention.

Fig. 2 is a partial sectional plan view of the embodiment of Fig. 1A taken along X-Y plane.

Figs. 3A and 3B are a partial sectional plan view and a partial sectional side view of a second embodiment of the invention taken along X-Y plane and X-Z plane respectively.

Fig. 4 is a partial sectional side view of a third embodiment of the invention taken along X-Z plane.

Fig. 5 is a partial sectional plan view of the embodiment of Fig. 4 taken along X-Y plane.

Fig. 6 is a partial sectional plan view of a sixth embodiment of the invention taken along X-Y plane.

Fig. 7 is a partial sectional plan view of a fifth embodiment of the invention taken along X-Y plane.

Fig. 8 is a partially cutaway schematic perspective view of a seventh embodiment of the invention.

Fig. 9 is an enlarged partial sectional plan view of the embodiment of Fig. 8 taken along X-Y plane.

Fig. 10 is an enlarged partial sectional plan view of an eighth embodiment of the invention taken along X-Y plane.

Fig. 11 is an enlarged partial sectional plan view of a ninth embodiment of the invention taken along X-Y plane.

Fig. 12 is an enlarged partial sectional plan view of a tenth embodiment of the invention taken along X-Y plane.

Fig. 13 is an exploded schematic perspective view of an eleventh embodiment of the invention, showing its principal components and their arrangement.

Fig. 14 is an enlarged schematic plan view of an electron-emitting region of an electron-emitting device to be used for the embodiment of Fig. 13.

Fig. 15 is an enlarged schematic partial plan view of the fluorescent layer of the embodiment of Fig. 13.

Fig. 16 is an exploded schematic perspective view of a twelfth embodiment of the invention, showing its principal components and their arrangement.

Fig. 17 is an exploded schematic perspective view of a thirteenth embodiment of the invention, showing its principal components and their arrangement.

Fig. 18 is an enlarged schematic partial plan view of the fluorescent layer of the embodiment of Fig. 17.

Fig. 19 is an exploded schematic perspective view of a fourteenth embodiment of the invention, showing its principal components and their arrangement.

Fig. 20 is a schematic partial sectional side view of a conventional flat type image-forming apparatus.

Fig. 21 is an enlarged schematic partial plan view of the fluorescent layer of a conventional flat type image-forming apparatus.

isfactorily without damaging the fluorescent layer and or the electron-emitting devices by appropriately arranging the spacer within the apparatus.

Now, a surface conduction electron-emitting device that can suitably be used for the purpose of the invention will be described.

Surface conduction electron-emitting devices to be used for the purpose of the present invention may be either of the flat type or of the upright type. Firstly, a flat type surface conduction electron-emitting device will be described.

Figs. 28A and 28B are a plan view and a side view of a flat type surface conduction electron-emitting device to be suitably used for an image-forming apparatus according to the invention, schematically showing its basic configuration.

Referring to Figs. 28A and 28B, a surface conduction electron-emitting device of the type under consideration comprises a substrate 3201, a pair of device electrodes 3205 and 3206 and a thin film 3204 including an electron-emitting region 3203.

Materials that can be used for the substrate 3201 include quartz, glass containing impurities such as Na to a reduced concentration level, sodalime glass, glass substrate realized by forming an SiO_2 layer on sodalime glass by means of sputtering, ceramic substances such as alumina and silicon wafer.

While the oppositely arranged device electrodes 3205 and 3206 may be made of any highly conducting material, preferred candidate materials include metals such as Ni, Cr, Au, Mo, W, Pt, Ti, Al, Cu and Pd and their alloys, printable conducting materials made of a metal or a metal oxide selected from Pd, Ag, RuO_2, Pd-Ag and glass, transparent conducting materials such as In_2O_3-SnO_2 and semiconducting materials such as polysilicon.

The distance L1 separating the electrodes is between hundreds angstroms and hundreds micrometers and determined as a function of various technical aspects of the photolithography to be used for manufacturing the device, including the performance of the aligner and the etching method involved, and the voltage to be applied to the electrodes as well as the electric field strength designed for electron emission. Preferably it is between several micrometers and tens of several micrometers. The lengths W1 and the thickness d of the device electrodes 3205 and 3206 may be determined on the basis of the requirements involved in designing the device such as the resistances of the electrodes and the arrangement of a plurality of electron sources provided in the apparatus, although the length W1 of the electrodes is normally between several micrometers and several hundred micrometers and the thickness d of the device electrodes 3205 and 3206 is typically between several hundred angstroms and several micrometers.

The thin film 3204 of the device is arranged between the device electrodes 3205 and 3206 oppositely disposed on the substrate 3201 and includes the electron-emitting region 3203. While the thin film 3204 including the electron-emitting region 3203 is partly laid on the device electrodes 3205 and 3206 in Fig. 28B, it may alternatively be so arranged as to be located off the device electrodes 3205 and 3206 on the substrate 3201. If such is the case, a thin film for forming an electron emitting region is firstly formed on a substrate 3201 and, thereafter, a pair of oppositely arranged device electrodes 3205 and 3206 are depositted on the substrate 3201 to produce such a device.

Still alternatively, it may be so arranged that all the areas of the thin film found between the oppositely arranged device electrodes 3205 and 3206 operates as an electron emitting region. The thickness of the thin film 3204 including the electron emitting region is preferably between several angstroms and several thousand angstroms and most preferably between 10 and 200 angstroms and is determined as a function of the stepped coverage of the thin film 3204 on the device electrodes 3205 and 3206, the resistance between the electron emitting region 3203 and the device electrodes 3205 and 3206, the mean size of the conducting particles of the electron emitting region 3203 and the parameters for the forming operation that will be described later as well as other factors. The thin film 3204 normally shows a sheet resistance between 10^3 and 10^7 Ω/□.

The thin film 3204 including the electron emitting region is made of fine particles of a material selected from metals such as Pd, Pt, Ru, Ag, Au, Ti, In, Cu, Cr, Fe, Zn, Sn, Ta, W and Pb, oxides such as PdO, SnO_2, In_2O_3, PbO and Sb_2O_3, borides such as HfB_2, ZrB_2, LaB_6, CeB_6, YB_4 and GdB_4, carbides such as TiC, ZrC, HfC, TaC, SiC and WC, nitrides such as TiN, ZrN and HfN, semiconductors such as Si and Ge, carbon, AgMg and NiCu.

The term "a fine particle film" as used herein refers to a thin film constituted of a large number of fine particles that may be loosely dispersed, tightly arranged or mutually and randomly overlapping (to form an island structure under certain conditions).

The electron emitting region 3203 is constituted of a large number of fine conductor particles with a mean particle size of between several and several thousands angstroms and preferably between 10 and 200 angstroms depending on the thickness of the thin film 3204 including the electron emitting region and a number of factors including the method selected for manufacturing the device and the parameters for the forming operation

scribed above come to have a Z-directional velocity component as an accelerating voltage is applied thereto mainly between the back plate 1001 and the face plate 1003 and also a +X- or -X-directional velocity component as they are deflected toward the respective device anodes. The electron beams eventually collide with the respective fluorescent members of electron beam irradiation arranged on the inner surface of the face plate and cause the latter to emit light to form images on the display screen of the apparatus. Note that the anti-atmospheric-pressure spacers do not interfere with any of the electron beams being accelerated by the accelerating voltage so that the electron beams collide with the respective fluorescent members as if there were no anti-atmospheric-pressure spacers arranged within the apparatus.

In this embodiment, the anti-atmospheric-pressure spacers 1004 are arranged in positional agreement with the respective boundary gaps (black stripes), each separating adjacent fluorescent targets from each other. In other words, the anti-atmospheric-pressure spacers 1004 are not located vis-a-vis any of the fluorescent targets. Additionally, they are arranged on the back plate in areas that are not occupied by the electron-emitting devices. It should be noted that the above statement holds true throughout the embodiments described herein with regard to the present invention.

In this embodiment, each of the anti-atmospheric-pressure spacers 1004 is rigidly fixed to the face plate 1003 and or the back plate 1001 by means of a frit glass fixture and held stationary by means of four anchor blocks, although each anti-atmospheric-pressure spacer may be held stationary with a reduced number of anchor blocks and fixed only to either the back plate or the face plate if such an arrangement ensures satisfactory strength and positional accuracy. Again, while each of the anti-atmospheric-pressure spacers is rigidly fixed to the enclosure 1002 at the opposite ends thereof in this embodiment, it may be secured to the enclosure 1002 only at an end thereof if satisfactory strength and positional accuracy is ensured by an arrangement

Besides, while the anti-atmospheric-pressure spacers are secured to the enclosure in this embodiment, they may alternatively be secured to a support frame arranged inside the enclosure. Although frit glass fixtures are used to rigidly hold the anti-atmospheric-pressure spacers or the anchor blocks in this embodiment, an adhesive agent may alternatively be used for the same purpose. Again, the above statement on the use of a support frame and an adhesive agent holds true throughout the embodiments described herein with regard to the present invention.

While Fig. 1A illustrates an image-forming apparatus comprising ten rows of electron-emitting devices and Fig. 2 shows that each row comprises four electron-emitting devices, the number of rows and the number of devices in each row are not limited thereto and they may be varied appropriately. The inside of the embodiment is evacuated by means of an exhaust pipe (not shown) and a vacuum pump and the exhaust pipe (not shown) is molten to hermetically seal the enclosure when the inside is evacuated to a degree of vacuum of approximately 10^{-6} Torr.

[Embodiment 2]

Figs. 3A and 3B illustrate a second embodiment of image-forming apparatus according to the invention. Fig. 3A shows a partial sectional plan view taken along X-Y plane while Fig. 3B shows a partial sectional side view taken along X-Z plane.

Referring to Figs. 3A and 3B, the embodiment comprises fluorescent targets 1010 formed on a face plate 1003 and anchor blocks 1005' for rigidly holding anti-atmospheric-pressure spacers 1004 to a face plate 1003.

This embodiment is characterized in that the anchor blocks 1005' for supporting and rigidly holding the anti-atmospheric-pressure spacers 1004 are arranged off the tracks of electron beams and fitted onto the face plate 1003 by means of frit glass fixtures.

Note that the anchor blocks 1005' may alternatively be fitted onto the back plate 1001 or both the face plate 1003 and the back plate 1001 if they do not interfere with the tracks of electron beams in the apparatus.

A more rigid anti-atmospheric-pressure structure may be obtained for this embodiment if anchor blocks 1005 of the type used in the first embodiment are also used in combination with the anchor blocks 1005' and fitted to the enclosure of this embodiment.

[Embodiment 3]

Figs. 4 and 5 illustrate a third embodiment of image-forming apparatus according to the invention. Fig. 4 is a partial sectional side view of a third embodiment of the invention taken along X-Z plane and Fig. 5 is a partial sectional plan view of the embodiment of Fig. 4 taken along X-Y plane.

Referring to Figs. 4 and 5, reference numeral 1009 denotes grooves for receiving respective anti-atmospheric-pressure spacers 1004, which are rigidly fitted into the grooves 1009 by means of frit glass fixtures 1006.

Note that this embodiment differs from Embodiment 1 only in that grooves are provided for

prises a plurality of spacers arranged along a line in parallel with the X-axis, each having a length A and any adjacent ones being separated from each other by a distance B in the row.

Then, two adjacent rows 1021 of anti-atmospheric-pressure spacers are arranged in such a way that one of the rows is displaced along the X-axis by a distance of (A + B) 2 relative to the other and the two rows are separated in Y-direction by ten rows of electron-emitting devices or a distance of C. All the rows of anti-atmospheric-pressure spacers are arranged in this manner within the image-forming apparatus.

In an experiment conducted by the inventors of the present invention for this embodiment, anti-atmospheric-pressure spacers made of glass and having a length A of 40mm, a thickness along the Y-axis of 0.2mm and a height along the Z-axis of 3mm were arranged within an image-forming apparatus according to the invention in such a way that any two adjacent anti-atmospheric-pressure spacers were separated from each other by a distance B along the X-axis of 40mm in a same row and any two adjacent rows of anti-atmospheric-pressure spacers were separated from each other by a distance C along the Y-axis of 15mm. Both the face plate and the back plate of the apparatus were square and had 300mm long edges and a thickness of 3mm. Then, a plurality of small anti-atmospheric-pressure spacers were arranged in each row in parallel with or substantially in parallel with the electron beams emitted from the electron-emitting devices of the apparatus and zigzag in directions perpendicular to the direction of electron beams. With such an arrangement, the inside of the apparatus could be evacuated effectively and efficiently to a high degree of vacuum. Additionally, since the surface area of each spacer was significantly reduced, the apparatus could maintain the improved internal vacuum condition for a prolonged period of time.

[Embodiment 8]

Fig. 10 is an enlarged partial sectional plan view of an eighth embodiment of image-forming apparatus according to the invention taken along X-Y plane, where the face plate is removed.

This embodiment is similar to the seventh embodiment and differs from the latter only in the distance separating any two adjacent anti-atmospheric-pressure spacers.

In an experiment conducted by the inventors of the present invention for this embodiment, anti-atmospheric-pressure spacers made of glass and having a length A of 40mm, a thickness along the Y-axis of 0.2mm and a height along the Z-axis of 3mm were arranged within an image-forming apparatus according to the invention in such a way that any two adjacent anti-atmospheric-pressure spacers were separated from each other by a distance B of 30mm along the X-axis in a same row and any two adjacent rows of anti-atmospheric-pressure spacers were separated from each other by a distance C along the Y-axis of 20mm. Both the face plate and the back plate of the apparatus were square and had 300mm long edges and a thickness of 3mm.

With this arrangement, the inside of the apparatus could be evacuated effectively and efficiently to a high degree of vacuum and the apparatus could maintain the improved internal vacuum condition for a prolonged period of time as in the case of Embodiment 7.

[Embodiment 9]

Fig. 11 is an enlarged partial sectional plan view of a ninth embodiment of image-forming apparatus according to the invention taken along X-Y plane, where the face plate is removed.

This embodiment is similar to the seventh and eighth embodiments and differs from the latter only in that rows of anti-atmospheric-pressure spacers with different sizes are alternately arranged.

Referring to Fig. 11, a row 1022 of anti-atmospheric-pressure spacers 1024 of a first type and a row 1025 of anti-atmospheric-pressure spacers 1023 of a second type are adjacently arranged. The anti-atmospheric-pressure spacer 1024 of the first type has a length of a1 along the X-axis, whereas the anti-atmospheric-pressure spacer 1023 of the second type has a length of a2 along the X-axis. Any two adjacent anti-atmospheric-pressurespacers 1024 of the first type are separated from each other by a distance of b1 along the X-axis in each row 1022 of anti-atmospheric-pressure spacers 1024 of the first type running along the X-axis, whereas any two adjacent anti-atmospheric-pressure spacers 1023 of the second type are separated from each other by a distance of b2 along the X-axis in each row 1025 of anti-atmospheric-pressure spacers 1023 of the second type running along the X-axis. Then, each row 1022 of anti-atmospheric-pressure spacers 1024 of the first type is separated from any adjacent row 1025 of anti-atmospheric-pressure spacers 1023 of the second type by ten rows of electron-emitting devices or a distance of C.

In an experiment conducted by the inventors of the present invention for this embodiment, anti-atmospheric-pressure spacers 1024 of the first type were made of glass and had a length a1 of 40mm, a thickness along the Y-axis of 0.2mm and a height along the Z-axis of 3mm, whereas anti-atmospheric-pressure spacers 1023 of the second type were

above.

(1) A glass substrate 1000 was thoroughly cleaned in an organic solvent and, thereafter, an electrode layer of nickel (Ni) was formed on the substrate 1000 to a thickness of 1,000Å. (See Figs. 13 and 14.) Then, a plurality of wires 2001 were formed with respective device electrodes 2004 along a direction perpendicular to the stripe-shaped fluorescent members arranged on the face plate side (along X-direction in Fig. 14) such that a pair of closely located device electrodes 2004 were separated from each other by a distance (L1 in Fig. 14) of 3µm and respectively connected to a pair of related wire sections 2001.

(2) After applying an organic palladium (ccp-4230 available from Okuno Pharmaceutical Co., Ltd.) containing solution to the glass substrate 1000 the latter was heat-treated at 300°C for ten minutes to form a film of fine particles of palladium oxide. Then, the film was subjected to a patterning operation, involving etching, to produce thin films 2006 for forming electron-emitting regions, each located between a pair of device electrodes 2004. (See Fig. 14.) Each of the thin film 2006 for forming an electron-emitting region was made to have a film thickness of 100Å and sheet resistance of $5\times10^{4}\Omega/\square$. The term "a fine particle film" as used herein refers to a thin film constituted of a large number of fine particles that may be loosely dispersed, tightly arranged or mutually and randomly overlapping (to form an island structure under certain conditions) and, whenever the expression "mean particle size" is employed, it refers only to that of recognizable fine particles.

(3) Thereafter, a given voltage was applied to the device sections 2004 of the device electrode layer 2005 to expose them to an electrically energizing process referred to as "electric forming" and produce an electron-emitting region between each appropriate pair of device sections 2004 of the device electrode 2005.

(4) As a number of electron-emitting devices were prepared along a plurality of rows of wire sections 2001, device-side ribs 2002 were then arranged in such a way that each rib 2002 runs at the middle between any two adjacent devices arranged along a wire section (X-direction). In other words, the ribs were arranged along the Y-axis in Fig. 14. The device-side ribs 2002 were made of frit glass having a low melting point and formed there by printing such that each of the ribs had a width and a height equal to 100µm.

(5) Then, the face plate 1003 was prepared in a manner as described below.

After thoroughly cleaning a glass substrate 2008 in a solution containing hydrofluoric acid, black stripes 2010 were formed thereon by photolithography, using graphite for a principal ingredient. (See Fig. 15.) Thereafter, a color fluorescent layer 2009 was formed on the glass substrate 2008 by means of a so-called slurry method, a technique popularly used for manufacturing CRTs, where each of coloring fluorescent materials for red, green and blue was mixed with photoresist to reduce it into a slurry-like state and then applied onto the glass substrate 2008 to produce stripe-shaped fluorescent members 2011 until stripes of all the three primary colors were formed. The formed stripes were then photographically developed and fixed. The fluorescent members 2011 were satisfactory in that they were evenly formed with a thickness ranging between 20 and 30µm.

(6) Thereafter, the surface of the fluorescent layer 2009 was smoothed by using a technique called "filming" and then a metal back layer (not shown) of aluminum was evenly formed on the inner surface of the fluorescent layer 2009 to a thickness of approximately 2,000Å by vacuum deposition.

(7) After producing the fluorescent layer 2009 and the metal back, fluorescent-layer-side ribs 2003 of frit glass were formed thereon to a thickness and a width of 100µm in such a way that each of the ribs 2003 was formed exactly on every third black stripe 2010 and therefore each rib was made responsible for three fluorescent members of different primary colors.

(8) The substrate 2000 carrying thereon a number of electron-emitting devices and the face plate 1003 were then oppositely disposed with a plurality of anti-atmospheric-pressure spacers 1004 and an enclosure 1002 arranged therebetween and frit glass was applied to the areas of the face plate 1003, the enclosure 1002 and the substrate 2000 to be bonded together before they were baked in the air or in a nitrogen atmosphere at temperature between 400°C and 500°C for more than ten minutes to hermetically seal the assembly of the components. Note that a number of grid electrodes (not shown) were also arranged for modulation within the embodiment. Then, identical pieces of plate glass, each having a height of 5mm and a thickness of 200µm, were arranged as so many spacers along a direction (X-direction) perpendicular to the ribs 2002 and 2003 disposed respectively on the substrate 2000 and the face plate 1003.

(9) Thereafter, the inside of the prepared glass enclosure assembly (comprising the substrate 2000, the enclosure 1002 and the face plate 1003) was evacuated by means of a vacuum pump through an exhaust pipe (not shown) to

approximately 10^{-6} Torr) embodiment can be remarkably reduced.

[Embodiment 13]

Fig. 18 shows an enlarged schematic partial plan view of the fluorescent layer of a thirteenth embodiment of image-forming apparatus according to the invention.

As seen from Fig. 18, the fluorescent members 2011 of this embodiment are arranged to show a so-called delta array. In Fig. 18, reference numeral 2012 denotes a black layer in which fluorescent members are arranged to show a matrix. If the distance separating any two most closely arranged fluorescent members of a same color (or dot pitch) is P in a delta array of fluorescent members, the horizontal distance of the two same color members is ($\sqrt{3}$)P/2, signifying that the entire display screen shows an improved resolution horizontally and is capable of displaying clear images.

Fig. 17 is an exploded schematic perspective view of the thirteenth embodiment comprising a delta array of fluorescent members, showing its principal components and their arrangement. As seen in F 17, both the device-side ribs 2002 and the fluorescent-layer-side ribs 2003 are realized in the form of a three-fingered starfish and arranged such that the ribs 2002 and 2003 are held in contact with respective cylindrical anti-atmospheric-pressure spacers 1004. With such an arrangement, the fluorescent layer 2009 and the device electrodes 2001 and 2004 are least liable to be damaged and, consequently, the embodiment can stably display clear images for a prolonged service life.

When any of the above described embodiments is used as a light source of an image recording apparatus, the latter operates stably to reproduce clear and flawless images.

[Embodiment 14]

Fig. 19 is an exploded schematic perspective view of a fourteenth embodiment of the invention, showing its principal components and their arrangement. Note that the back plate is directionally arranged in Fig. 19 same as that of Fig. 1B.

A back plate carrying thereon a number of electron-emitting devices and wires arranged in the form of a matrix on an X-Y plane as illustrated in Fig. 1B and used for the first embodiment is also used for this embodiment and, as shown in Fig. 19, device-side ribs 2002 are arranged on the back plate along a direction perpendicular to that of deflection of electron beams emitted from the electron-emitting devices as in the case of the eleventh embodiment. Then, a plurality of small anti-atmospheric-pressure spacers 3004 having a length L' smaller than the length L of the enclosure 1002 along the X-axis are arranged in parallel with the direction of deflection of electron beams emitted from the devices. Additionally, a certain number of small anti-atmospheric-pressure spacers are arranged in a zigzag manner along a direction (Y-direction) perpendicular to the direction of arrangement of the above mentioned small spacers.

Along with these components, a face plate carrying a fluorescent layer and provided with a number of fluorescent-layer-side ribs 2003 as that of the eleventh embodiment illustrated in Fig. 15 is used to form an image-forming apparatus. Any known techniques may be used for the evacuation of the apparatus and the process of utilizing a getter.

Again, since there exists practically nothing that interferes with the conductance in the embodiment when it is evacuated, the time required for hermetically sealing the evacuated (to a degree of vacuum of approximately 10^{-6} Torr) embodiment can be remarkably reduced. Additionally, since anti-atmospheric-pressure spacers can be arranged between the face plate and the substrate without damaging the fluorescent layer and the electrode layer for electron-emitting devices, the entire apparatus can be assembled without any problem. Finally, since the arranged anti-atmospheric-pressure spacers are least liable to be unintentionally displaced, the tracks of emitted electron beams are free from interference and, therefore, the apparatus can display clear images for a prolonged service life even if it is occasionally subjected to strain and stress.

[Embodiment 15]

Fig. 26 is a schematic perspective view of a fifteenth embodiment of image-forming apparatus according to the invention. This embodiment is obtained by replacing the back plate of the eleventh embodiment (comprising a glass substrate 1001 and electron-emitting devices formed thereon as illustrated in Fig. 13) with the back plate 1001 of the first embodiment (as illustrated in Fig. 1B). In Fig. 26, the components same as those of the first and eleventh embodiments are denoted by the same reference symbols.

Referring to Fig. 26, the embodiment comprises a glass substrate 1001, an enclosure 1002, a face plate 1003, a number of anti-atmospheric-pressure spacers 1004 arranged substantially in parallel with the X-axis, a number of electron-emitting devices formed on the glass substrate 1001 and arranged to show a matrix and wires for applying the respective electron-emitting devices to cause them to emit electrons.

nor color breakup in the display screen were observed if the glass substrate 1001 and the face plate 1003 were slightly misaligned in Y-direction. Additionally, the spacers 1004 do not require accurate mutual alignment in X- and Y-directions when they are arranged on the face plate 1003 (in parallel with the X-axis) and it is sufficient for them to be arranged with regular intervals in correspondence with the respective electron-emitting devices.

The above embodiment may be modified in many different ways. For example, a device-side rib 2002 may be provided for every several electron-emitting devices or a fluorescent-layer-side rib may be provided for every three stripe-shaped fluorescent members for red, green and blue.

[Advantages of the Invention]

As described above in detail, in an image-forming apparatus according to the invention and comprising, in particular, surface conduction electron-emitting devices, there is provided a panel structure where the tracks of electron beams emitted from the electron-emitting devices are made free from obstruction as a result of arranging anti-atmospheric-pressure spacers in parallel with the direction of deflection of electron beams emitted from the electron-emitting devices. Therefore, an image-forming apparatus according to the invention has, above all, the following advantages.

(1) The apparatus is free from any loss in the rate of collision of electrons with the fluorescent layer and, therefore, the fluorescent layer can stably and efficiently emit light for image display.

(2) The apparatus is free from any swerved tracks of electrons that can be brought forth by undesired changes in the distribution of electric potential due to charged-up anti-atmospheric-pressure spacers in the apparatus and also free from any destruction of devices that can be brought forth by creeping discharge due to reduction in the withstand creeping voltage.

(3) The apparatus can have a light emitting section that can emit light efficiently to a high degree of brightness because it can have an enhanced withstand creeping voltage and hence a high accelerating voltage.

(4) The apparatus can display highly defined clear images because electron-emitting devices and anti-atmospheric-pressure spacers can be densely arranged in the apparatus.

(5) The apparatus can be manufactured efficiently because the conductance in the apparatus can be improved by using small anti-atmospheric-pressure spacers.

(6) The apparatus can have an improved capability for maintaining a high degree of vacuum within the apparatus because the entire surface area of the spacers comprised in the apparatus can be reduced by arranging small anti-atmospheric-pressure spacer in a zigzag manner. Additionally, the apparatus has the following advantage when it comprises device-side and fluorescent-layer-side ribs.

(7) The apparatus is free from damage on the devices and the fluorescent members if the anti-atmospheric-pressure spacers are arranged with slight displacement or deformation because the anti-atmospheric-pressure spacers for separating the substrate and the face plate are not held in touch with the electron-emitting devices and the fluorescent members. Hence, the entire apparatus can be assembled with a lesser degree of elaboration and display clear images for a prolonged service life.

An image-forming apparatus comprises a back plate carrying thereon a plurality of electron-emitting devices, a face plate arranged vis-a-vis the back plate and carrying thereon a fluorescent member and an anti-atmospheric-pressure spacer. The longitudinal axis of the anti-atmospheric-pressure spacer is arranged substantially in parallel with the direction of deflection of electron beams emitted from said electron-emitting devices.

Claims

1. An image-forming apparatus comprising a back plate carrying thereon a plurality of electron-emitting devices, a face plate arranged vis-a-vis the back plate and carrying thereon a fluorescent member and an anti-atmospheric-pressure spacer, characterized in that the longitudinal axis of the anti-atmospheric-pressure spacers is arranged substantially in parallel with the direction of deflection of electron beams emitted from said electron-emitting devices.

2. An image-forming apparatus according to claim 1, wherein a plurality of said anti-atmospheric-pressure spacers are arranged in a row running substantially in perpendicular to the direction of deflection of electron beams.

3. An image-forming apparatus according to claim 2, wherein each of said anti-atmospheric-pressure spacers comprises a plurality of small spacers.

4. An image-forming apparatus according to claim 3, wherein the plurality of small spacers constituting said plurality of anti-atmospheric-

FIG. 1A

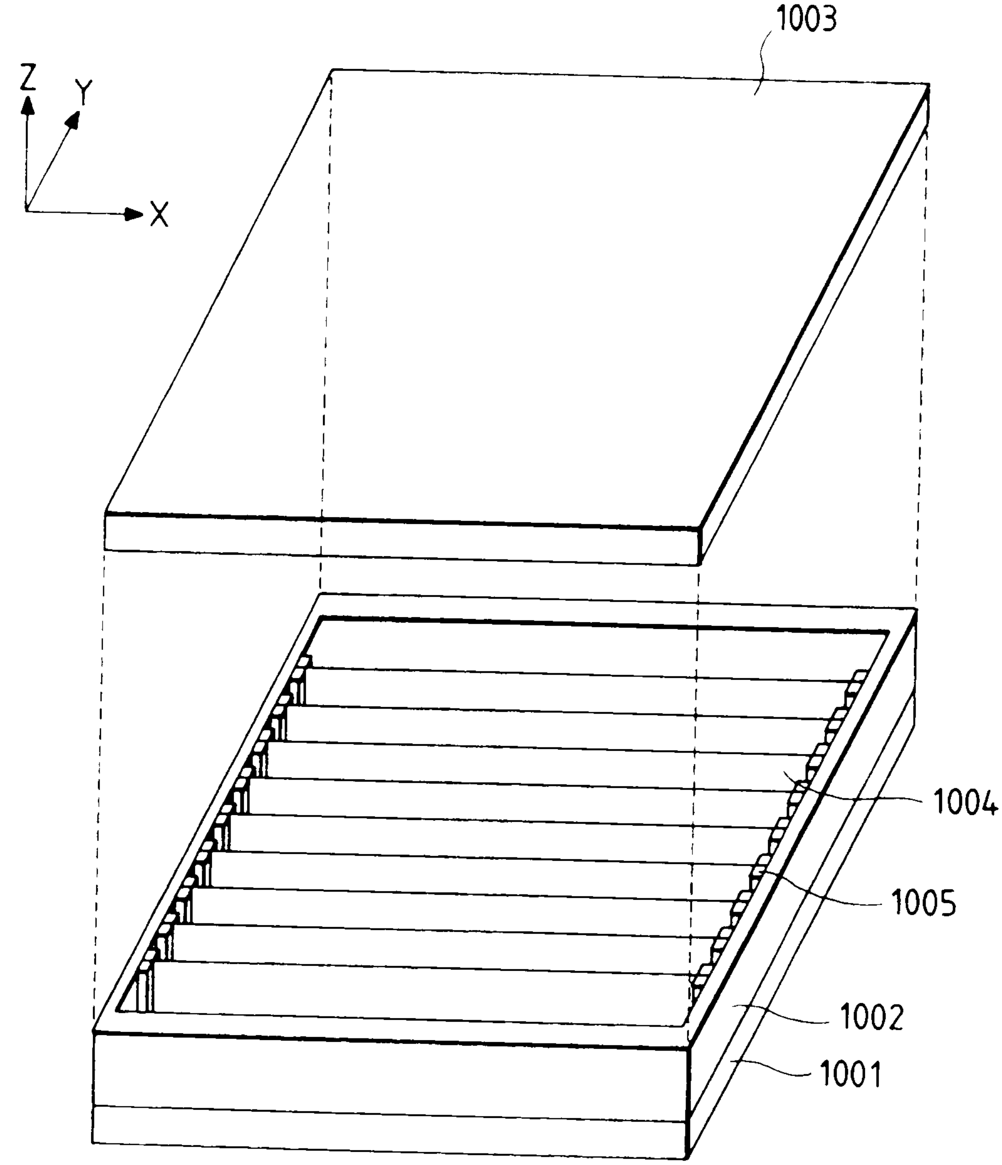


FIG. 1C

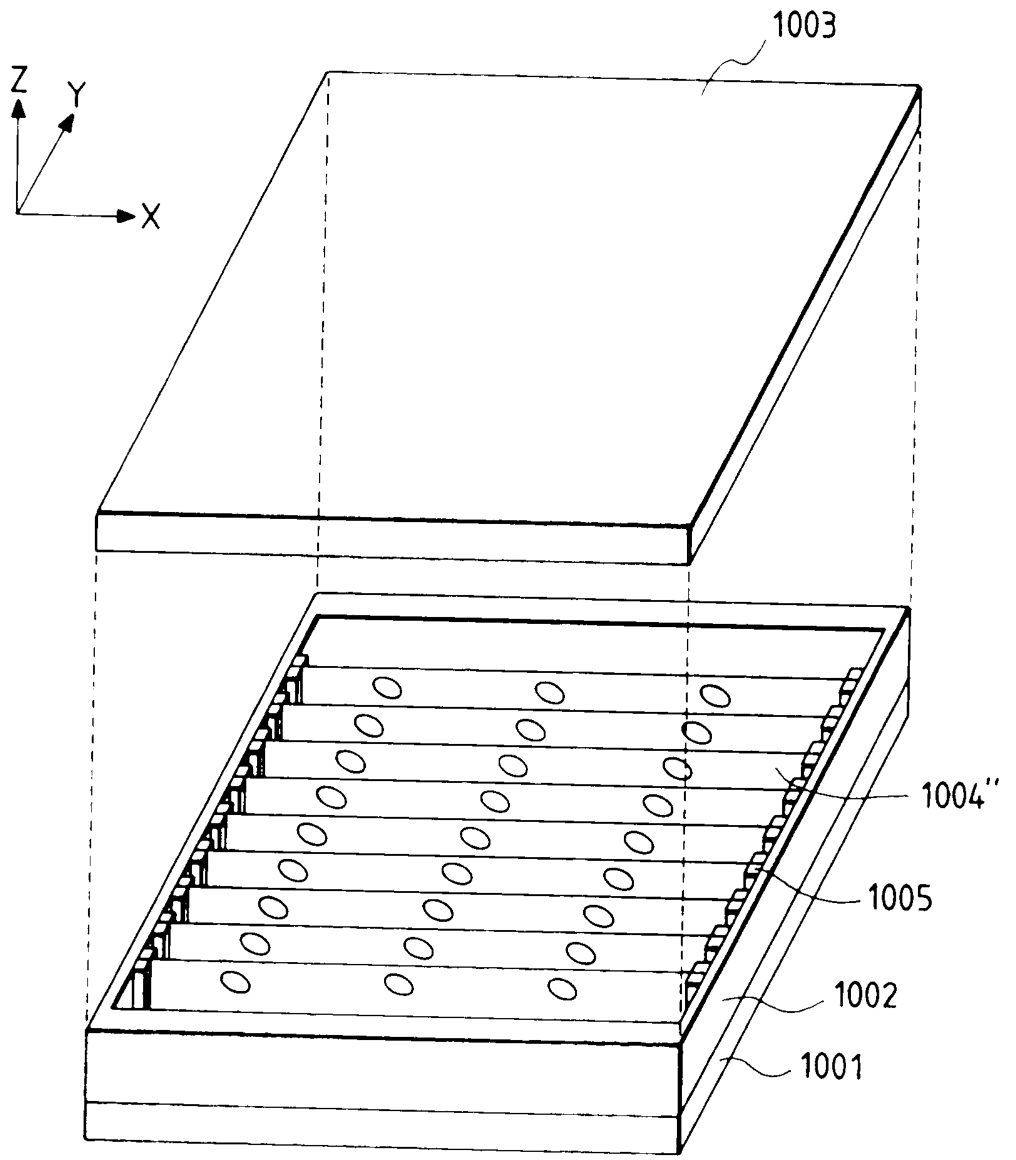


FIG. 3A

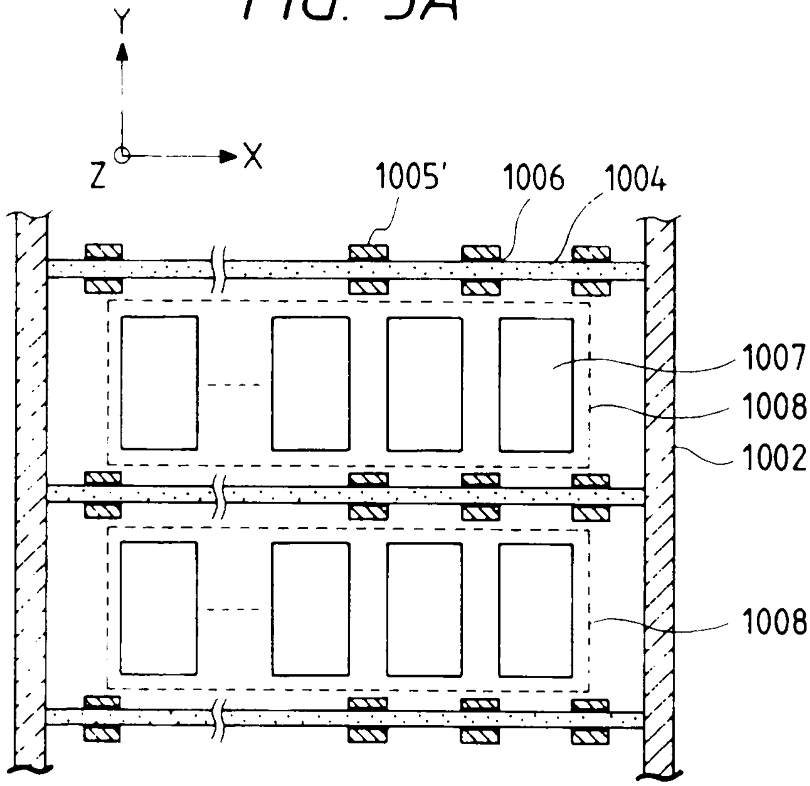

Y
X
Z
1005'
1006
1004
1007
1008
1002
1008

FIG. 3B

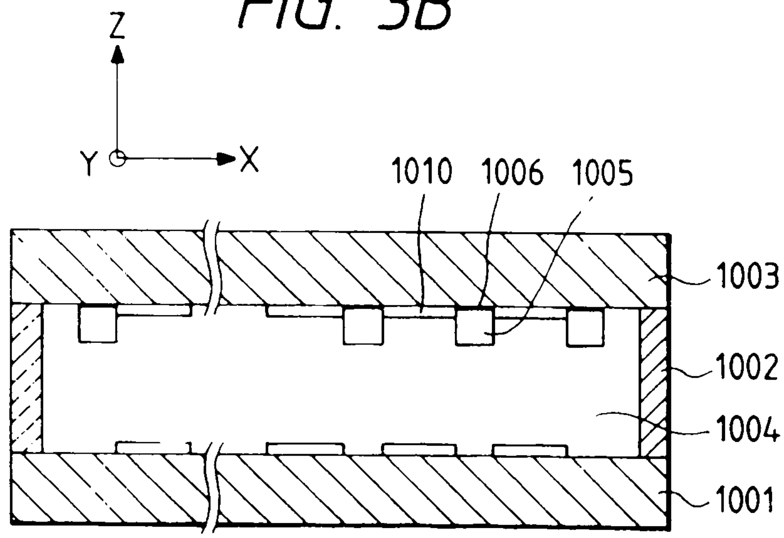

Z
Y
X
1010
1006
1005
1003
1002
1004
1001

FIG. 6

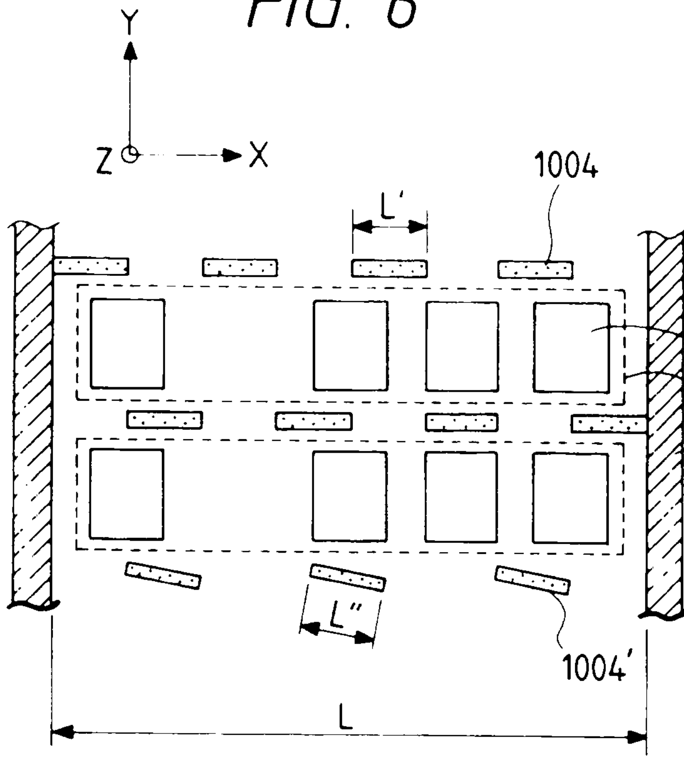

Y
Z
X
1004
L'
1007
1008
1002
L''
1004'
L

FIG. 7

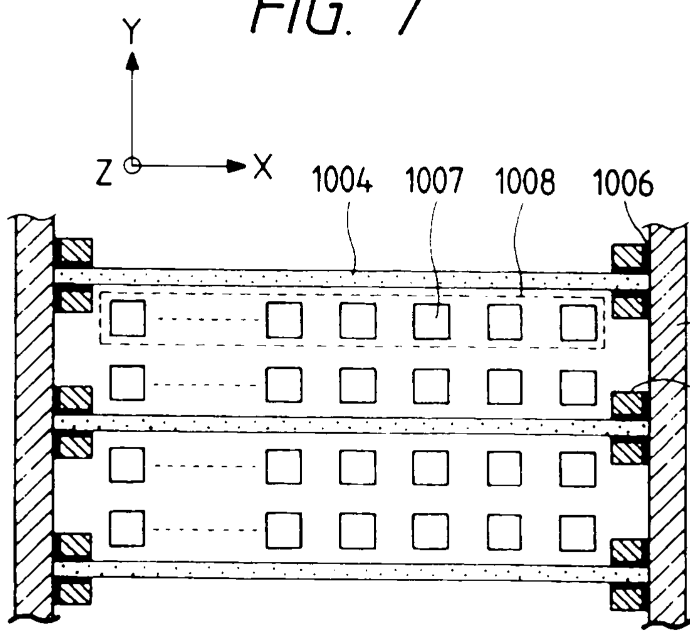

Y
Z
X
1004
1007
1008
1006
1002
1005

FIG. 9

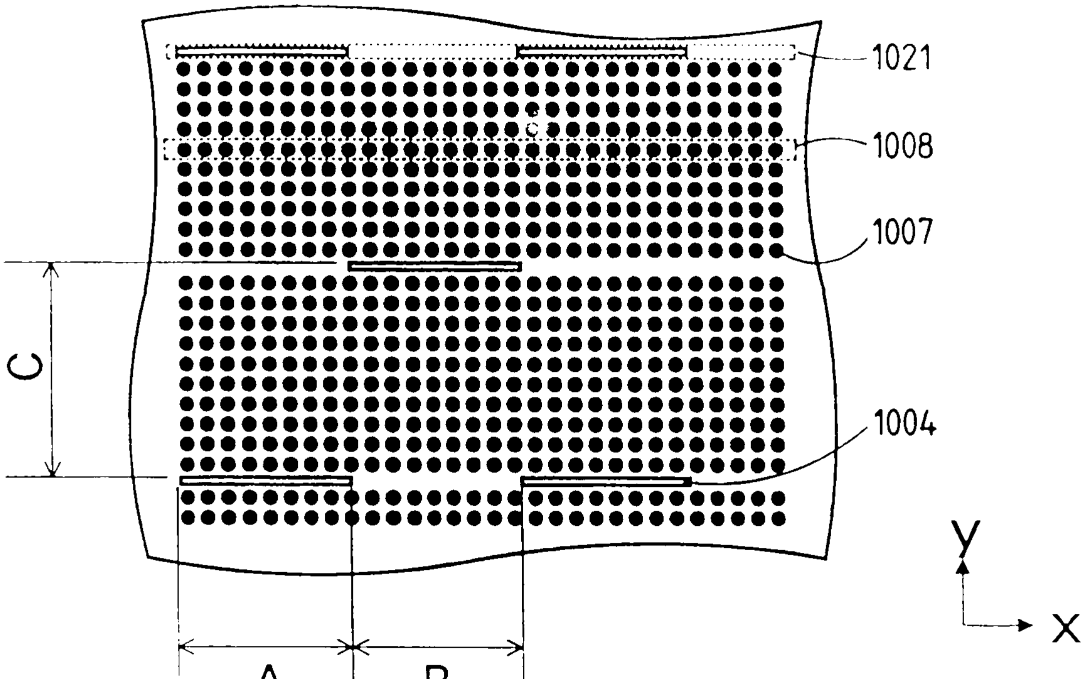


FIG. 10

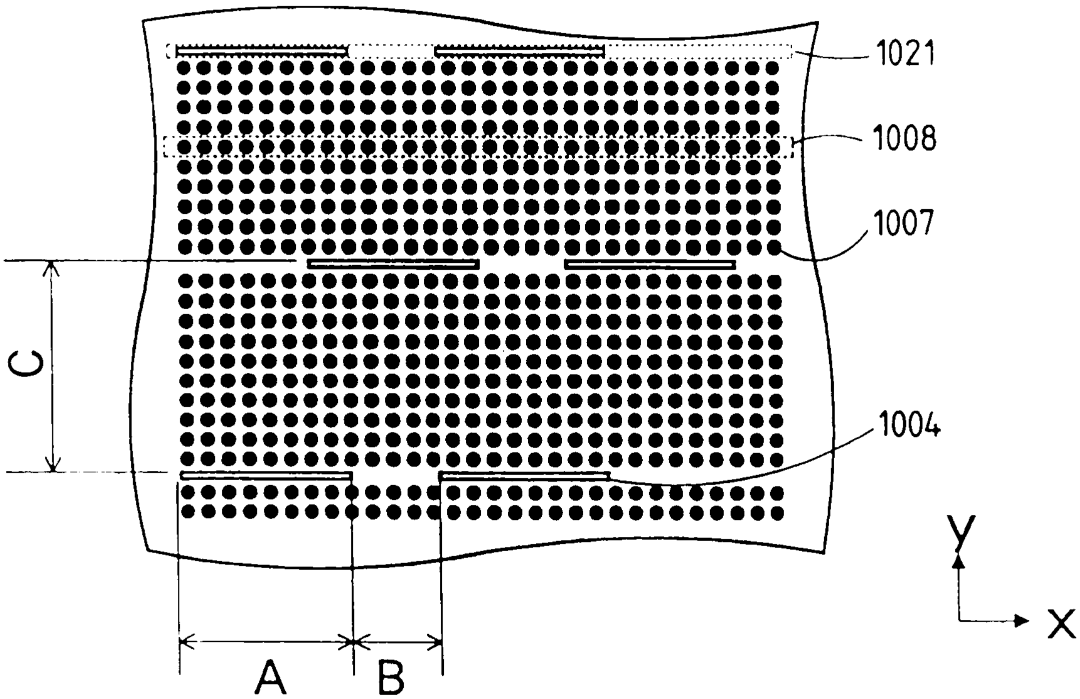
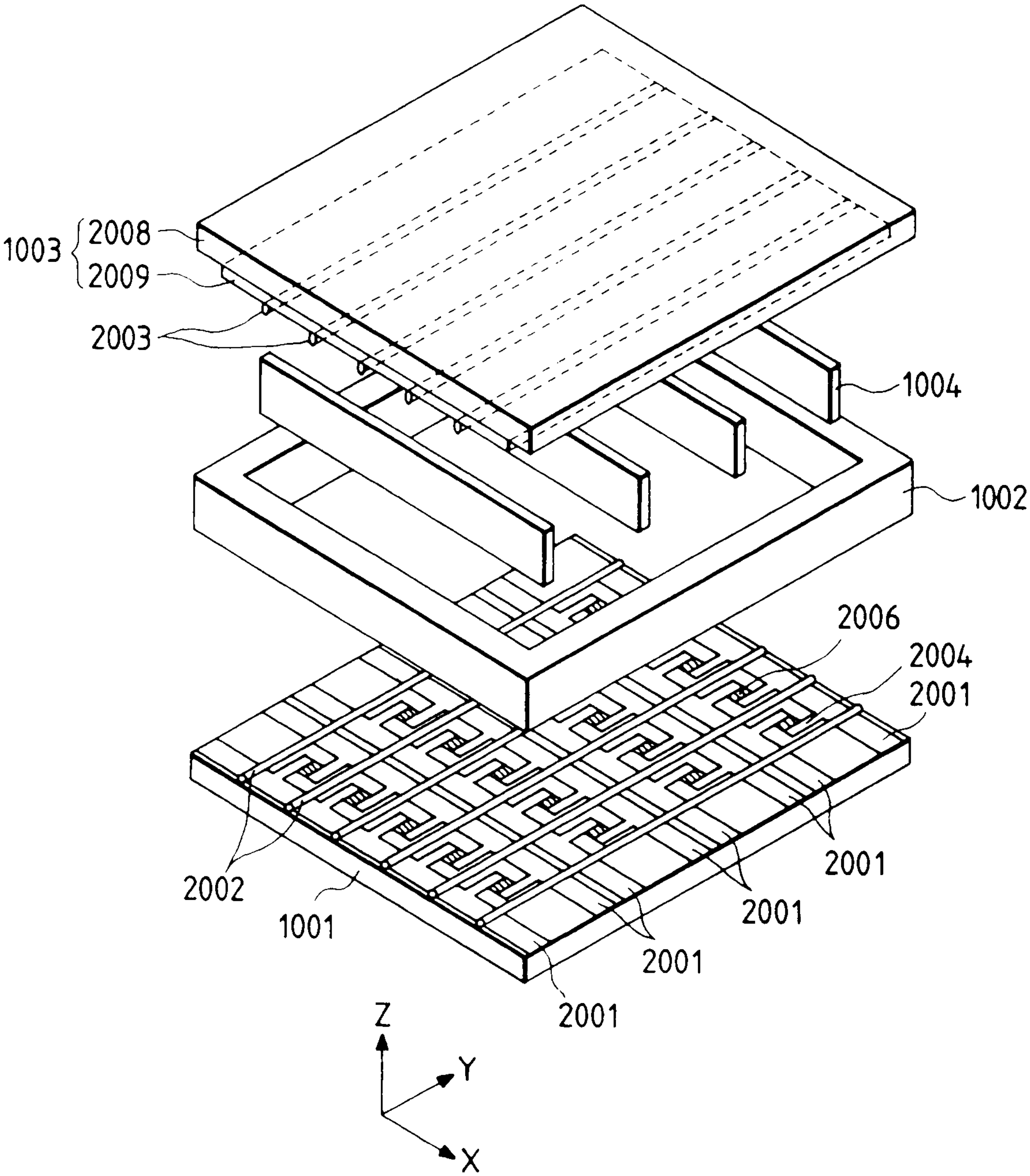


FIG. 13


1003
2008
2009
2003
1004
1002
2006
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2001
2001
2001
2001
2001
2001
2002
1001
Z
Y
X

FIG. 16

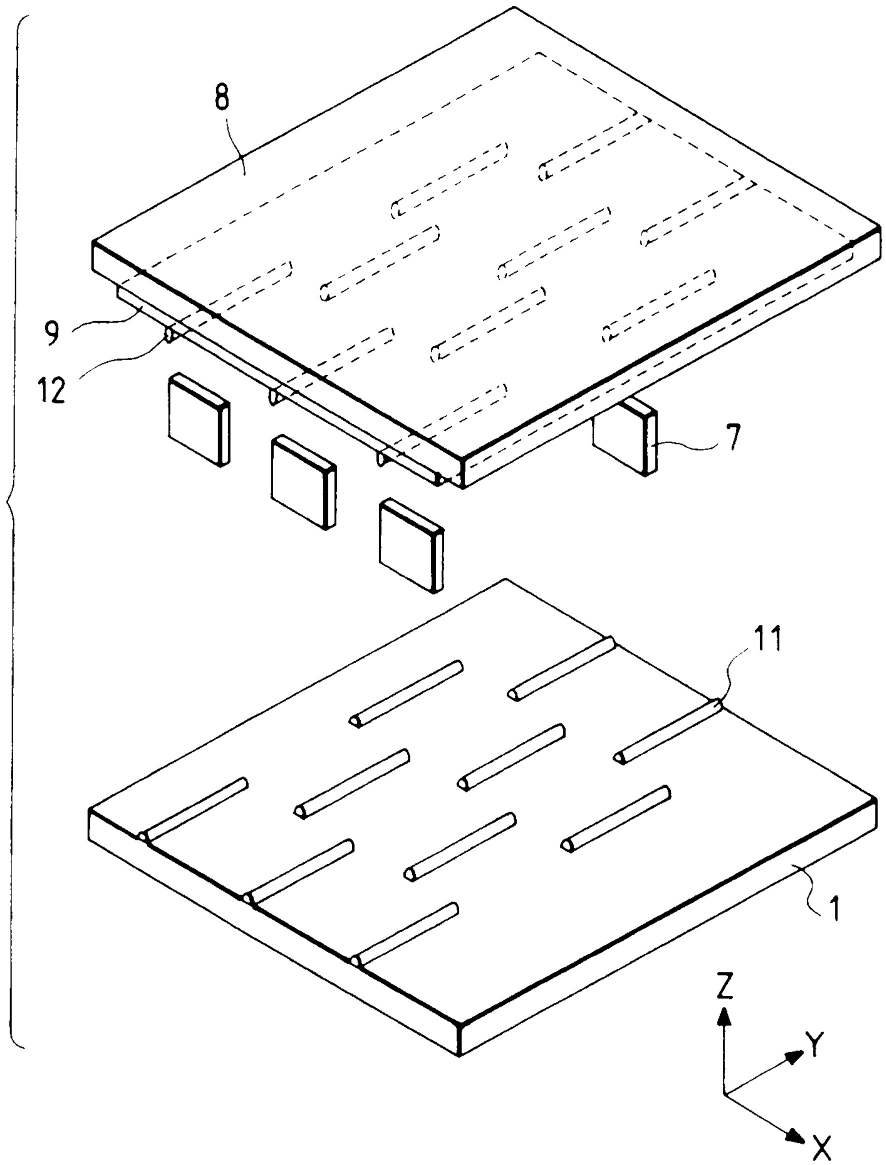


FIG. 19

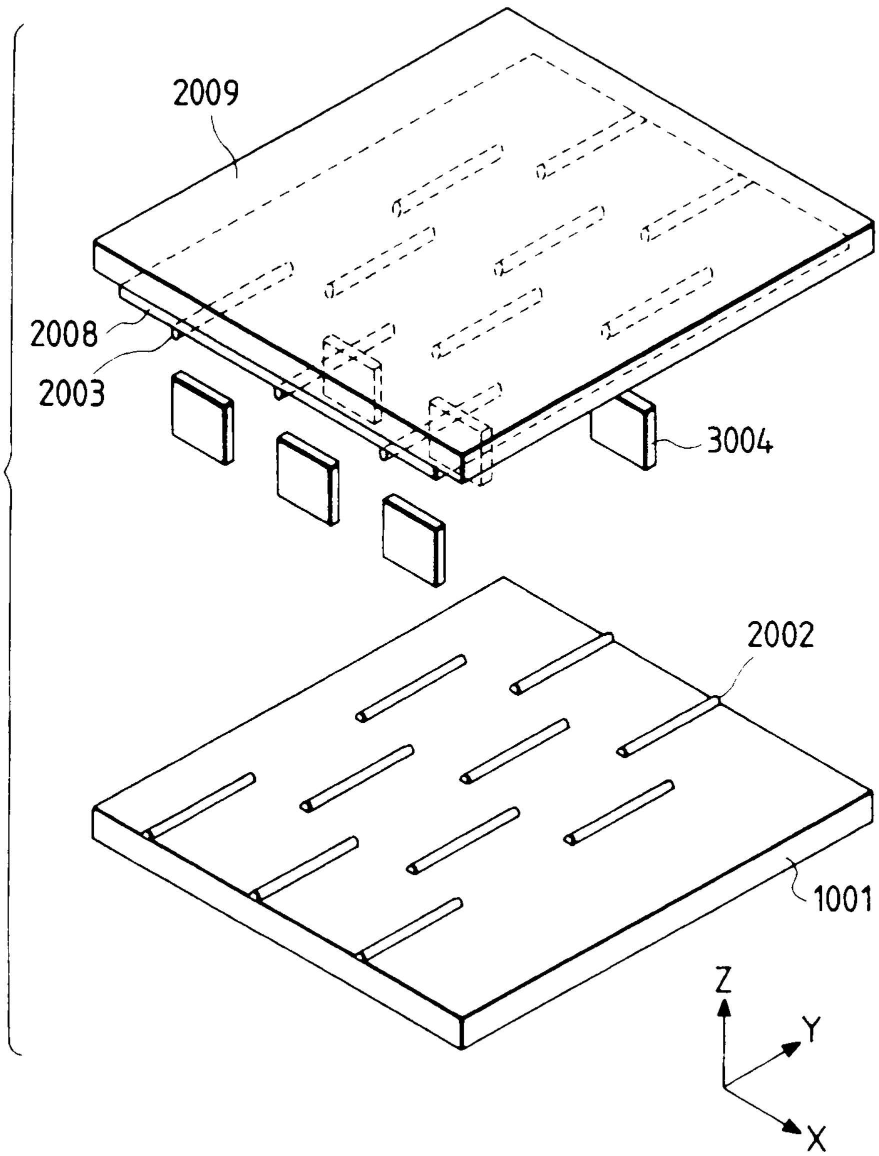


FIG. 22
PRIOR ART

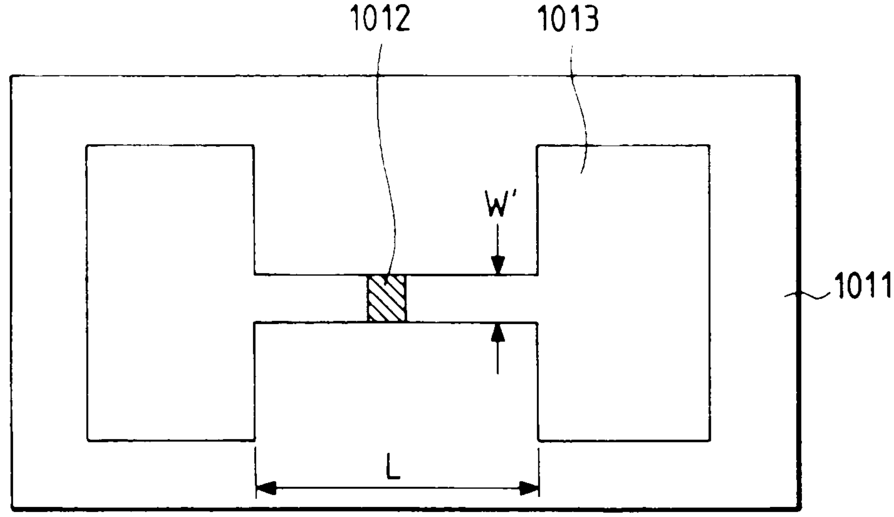


FIG. 23A

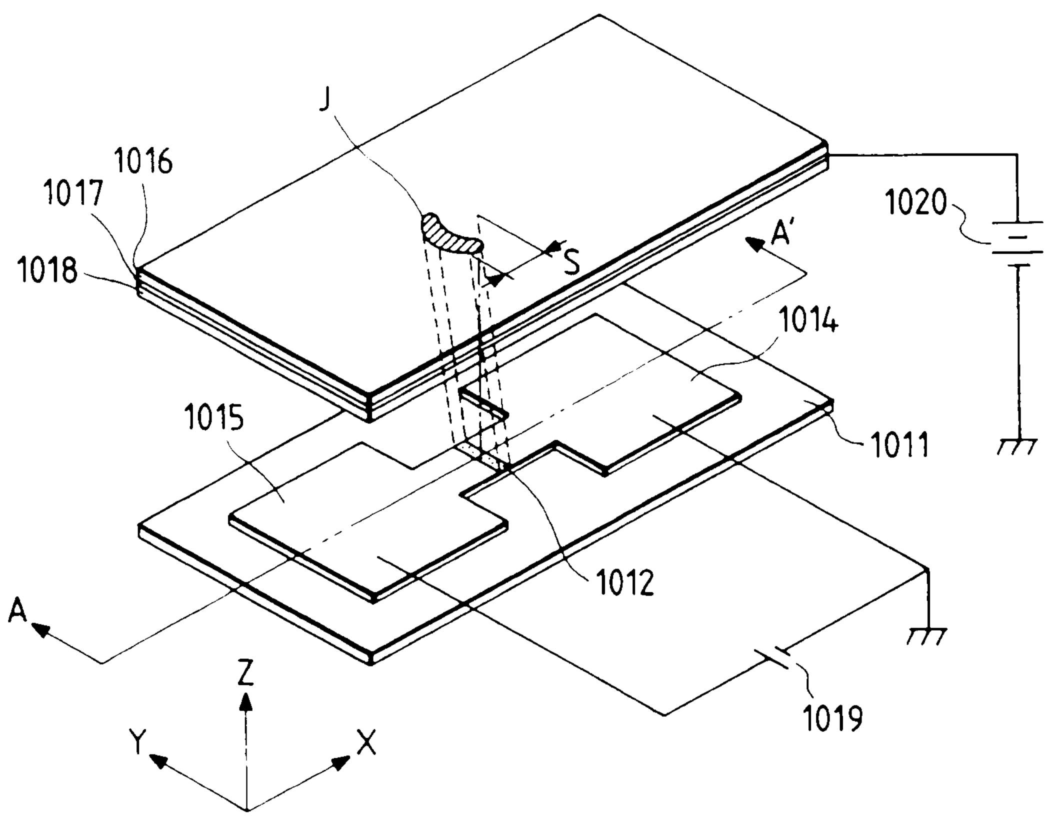


FIG. 25

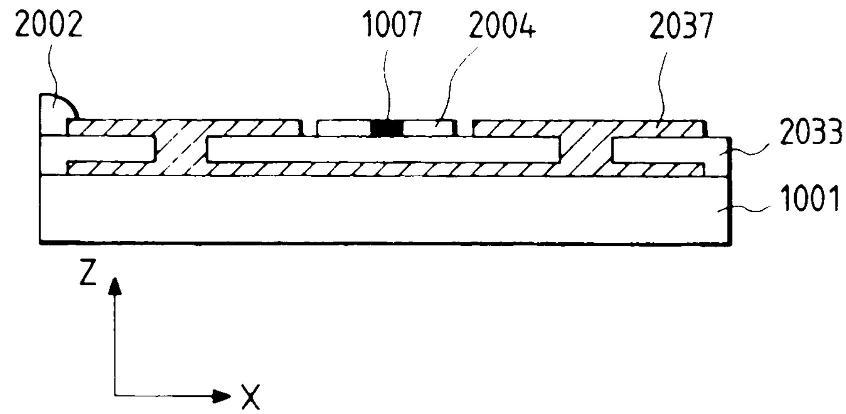

2002
1007
2004
2037
2033
1001
Z
X

FIG. 26

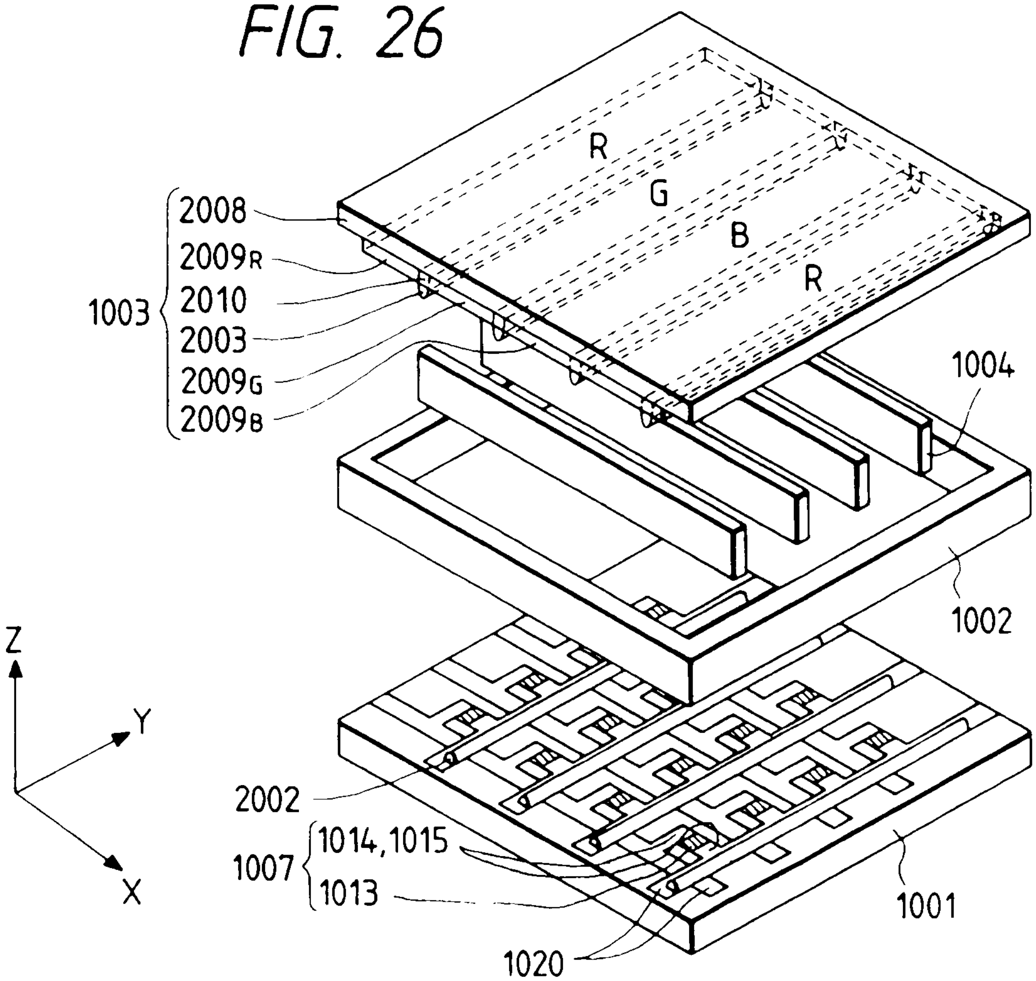
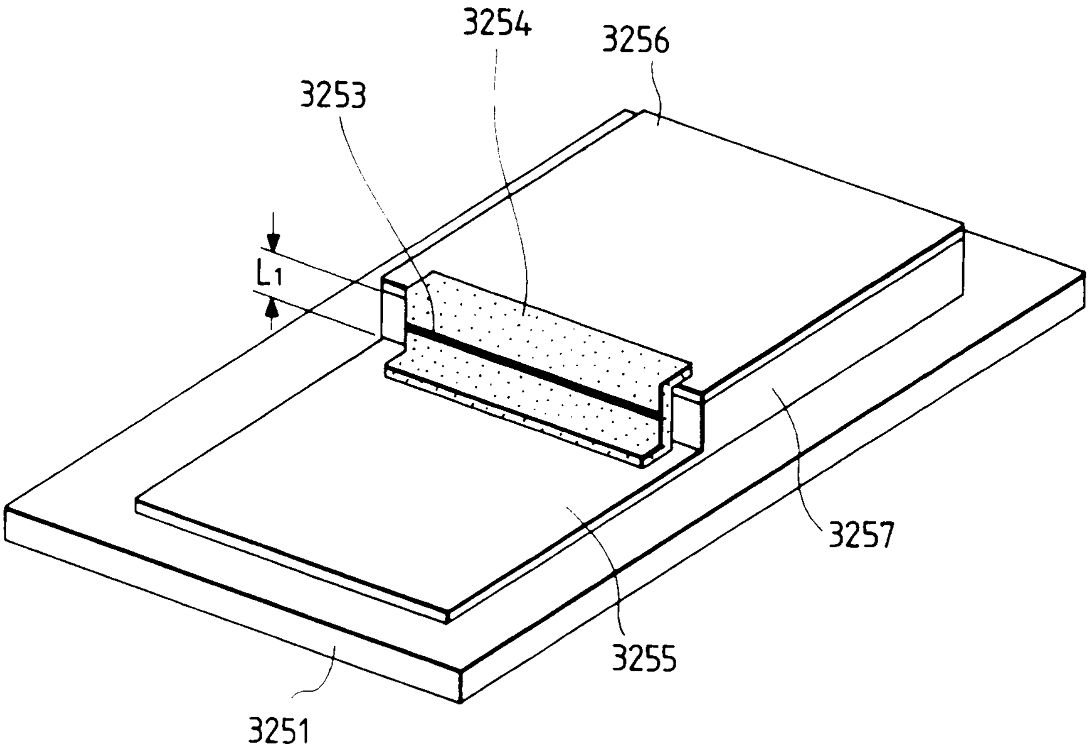

R
G
B
R
2008
2009R
2010
2003
2009G
2009B
1003
1004
1002
Z
Y
X
2002
1007
1014,1015
1013
1001
1020

FIG. 29



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(54) Image-forming apparatus.

(57) An image-forming apparatus comprises a back plate carrying thereon a plurality of electron-emitting devices, a face plate arranged vis-a-vis the back plate and carrying thereon a fluorescent member and an anti-atmospheric-pressure spacer. The longitudinal axis of the anti-atmospheric-pressure spacer is arranged substantially in parallel with the direction of deflection of electron beams emitted from said electron-emitting devices.

EP 0 631 295 A3

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EUROPEAN SEARCH REPORT

Application Number
EP 94 10 7761

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	EP-A-0 523 702 (CANON KABUSHIKI KAISHA) * figure 17 * * column 13, line 29 - line 39 * * column 20, line 37 - line 44 *	1,5,6	H01J9/18 H01J31/12
Y		10,11	
X	EP-A-0 493 804 (CANON KABUSHIKI KAISHA) * column 6, line 9 - line 18 * * column 7, line 3 - line 14 * * figure 1 *	1,5,6	
A		12	
X	EP-A-0 405 262 (MATSUSHITA ELECTRIC INDUSTRIAL CO.) * figures 12,13 * * column 6, line 3 - line 17 * * column 11, line 25 - column 13, line 51 *	8	
Y		10,11	
A		12	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
D,A	PATENT ABSTRACTS OF JAPAN vol. 15, no. 82 (E-1038) 26 February 1991 & JP-A-02 299 136 (CANON INC.) 11 December 1990 * abstract *	1,12	H01J
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 December 1994	Colvin, G

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X : particularly relevant if taken alone
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LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions,
namely:

1. Claims 1-7,12-19 : Geometric spacer arrangement relative to electron beam deflection direction.

2. Claims 8-11 : Fixing of spacers.

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Datum/Date
09.02.98

Zeichen/Ref./Réf.	Anmeldung Nr./Application No./Demande n°./Patent Nr./Patent No./Brevet n°.
2373140	97204007.5-1240-
Anmelder/Applicant/Demandeur/Patentinhaber/Proprietor/Titulaire CANON KABUSHIKI KAISHA	

COMMUNICATION

The European Patent Office herewith transmits as an enclosure the European search report for the above-mentioned European patent application.

If applicable, copies of the documents cited in the European search report are attached.

[X] Additional set(s) of copies of the documents cited in the European search report is (are) enclosed as well.

The following specifications given by the applicant have been approved by the Search Division:

[X] abstract [ ] title

[ ] The abstract was modified by the Search Division and the definitive text is attached to this communication.

The following figure will be published together with the abstract: 9

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REFUND OF THE SEARCH FEE

If applicable under Article 10 Rules relating to fees, a separate communication from the Receiving Section on the refund of the search fee will be sent later.

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 20 4007

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
P,Y	EP 0 631 295 A (CANON KK) * figures 6,8-11,16,19 * * column 14, line 1 - line 12 * * column 24, line 50 - column 25, line 2 *	1,3	H01J9/385 H01J9/18
A		2	

Y	EP 0 451 362 A (MITSUBISHI ELECTRIC CORP) * figures 1,7 * * column 8, line 47 - column 9, line 9 *	1,3	
A		2	

A	WO 88 01098 A (COMMTECH INT) * figures 2,3,5 * * page 8, line 25 - page 9, line 6 * -----	1,2	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H01J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	2 February 1998	Colvin, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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02-02-1998

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		US 5015912 A	14-05-91

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